

4th Annual X-band Structure Collaboration Meeting

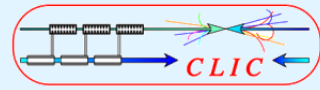
Manufacturing RF structures at CERN

G. Riddone, 04/05/2010

(contribution from Production Team: S. Atieh, G. Arnau, Ph. De Souza, A. Grudiev, D. Gudkov, T. Katopodis, S. Lebet, M. Filippova, M. Malabaila, A. Olyunin, A. Samoshkin, J. Shi, M. Saifoulina, A. Solodko, I. Syratchev, M. Taborelli, T. Uusimaeki)



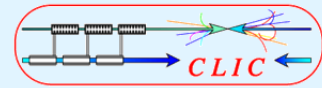
Content



- Scope: RF acceleration structures, PETS and RF components
- Production flow: accelerating structures and PETS
- Production program and status
- Production capability and master schedule
- Dedicated test program
- Conclusions



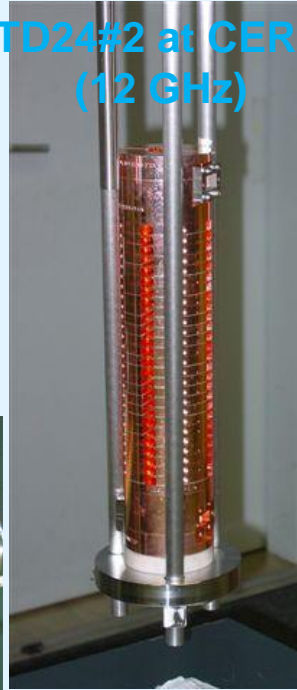
Scope



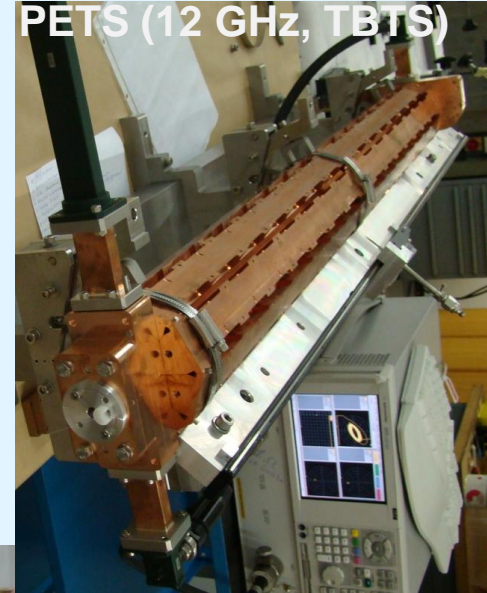
TD18#3 at SLAC



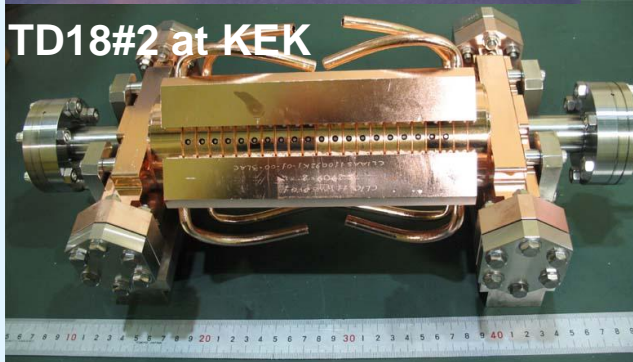
TD24#2 at CERN
(12 GHz)



PETS (12 GHz, TBTS)



TD18#2 at KEK



PETS (11.4 GHz, test at SLAC)

High-power dry load

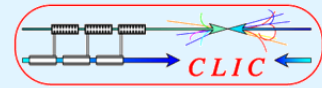


Hybrid



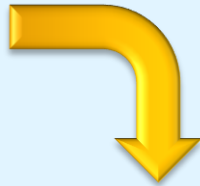
Variable high power splitter

Baseline procedure

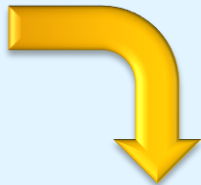


NLC/JLC fabrication technology:
validated to 100 MV/m (baseline
adopted in 09.2011)

Diamond
machining (disks,
sealed structures)



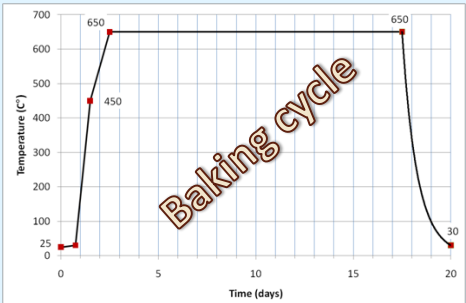
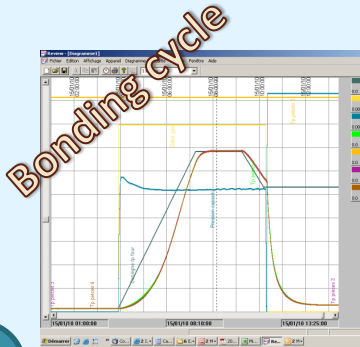
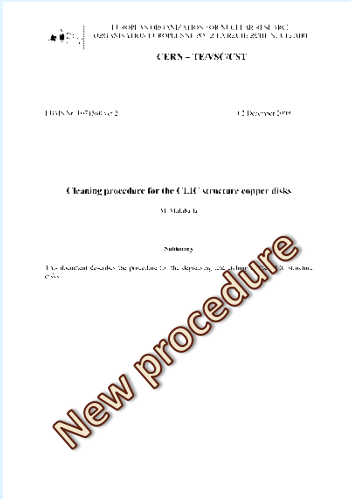
Cleaning with light
etch



H2 diffusion
bonding/brazing at
 $\sim 1000\text{ }^{\circ}\text{C}$

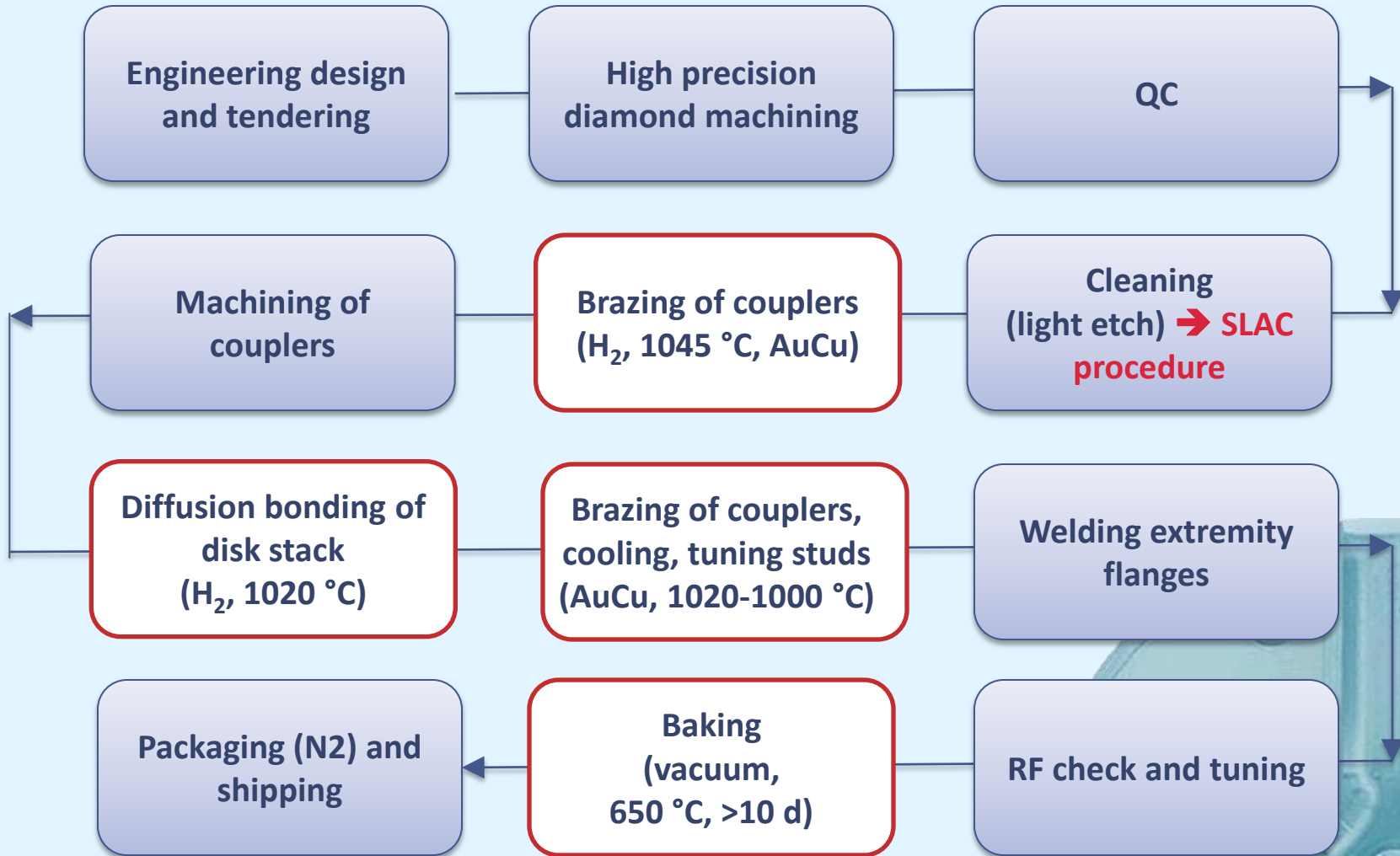
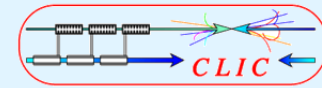


Vacuum baking
 $650\text{ }^{\circ}\text{C} > 10\text{ days}$





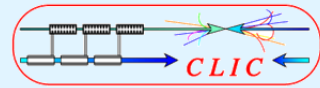
Accelerating structures: baseline manufacturing flow



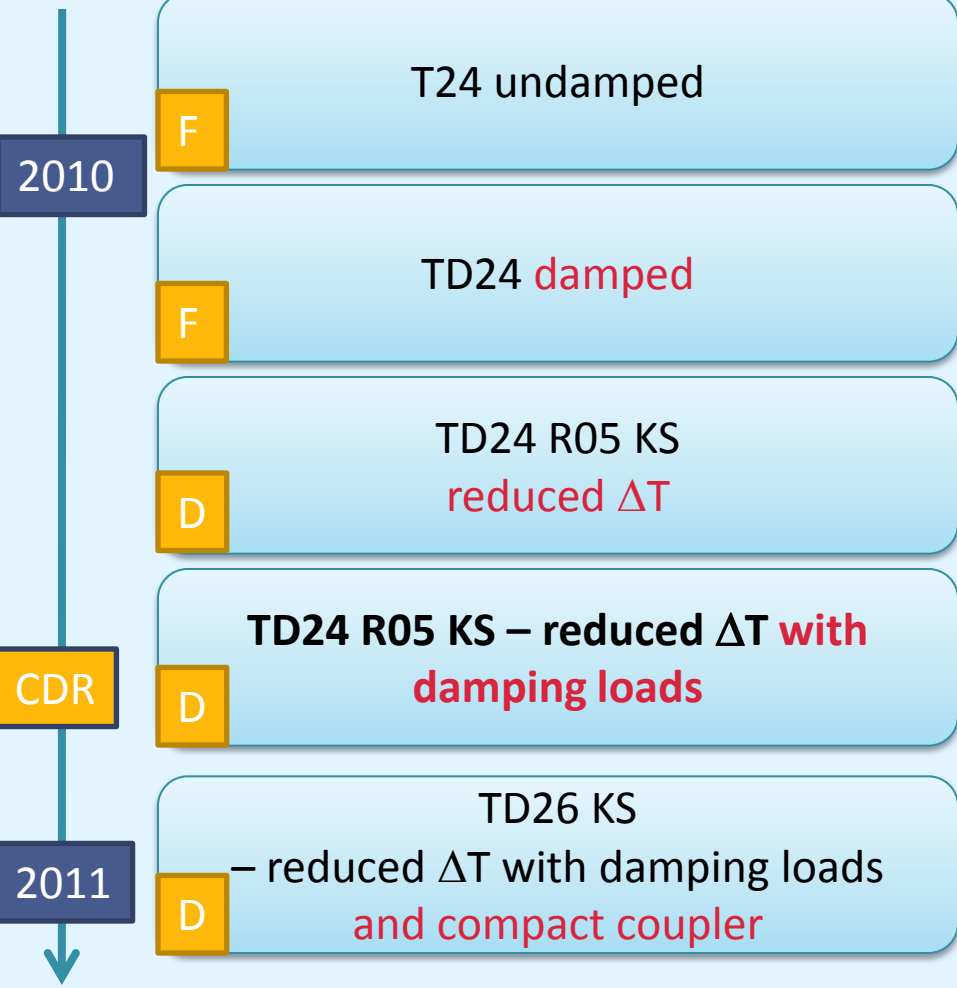
*Witness sample for each fabrication step
brazing./bonding: 30 mbar H2*



Production base program



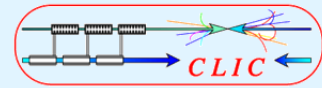
F = under fabrication
D = under eng. design





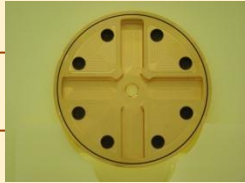
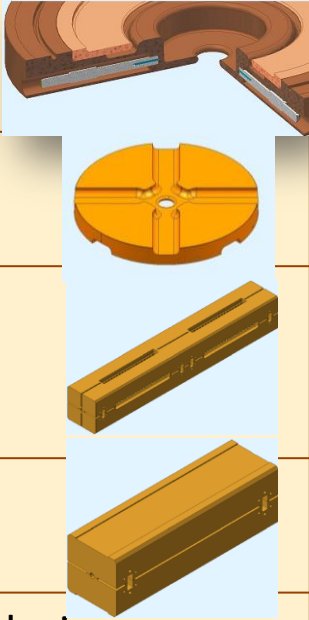
F TD24 – with wakefield monitors

D CLIC structures with all features and technical systems

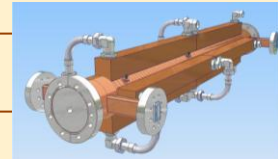
Production program



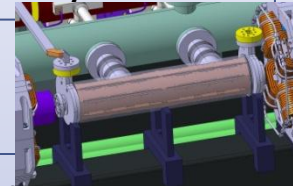
Accelerating structure		Frequency	[#]	Status	Comments
T18 KS	11 GHz	2	1 baking 1 bonding	Baseline design	
T24	11 GHz	1	Disks at CERN	Previous CERN design	
T24 45 mm	12 GHz	2	1 bonding		
T24 45 mm	11 GHz	2	Disks at CERN		
TD24	12 GHz	1	Installed TBTS	Previous CERN design	
T24 KS	12 GHz	2+1	Machining		Baseline design
T24 KS	11 GHz	2+1	Machining		
TD24 KS	11 GHz	2	Machining		
TD24 KS	12 GHz	2	Tendering		
TD24 WFM	12 GHz	2+1	Tendering		
TD24 R05 KS	12 GHz	2	Eng. design	Baseline, lower DT	
TD24 SiC R05	12 GHz	2	RF design available	With damping loads	
TD26 KS	12 GHz	2	RF design on-going	With compact coupler	

Accelerating structure		[#]	Status		Comments
CD10	11 GHz	2	Disks at CERN		vg1.16
C10	11 GHz	2	Machining		vg1.35
CD10 choke Proto + full str.	=	=	Machining		New damping (Tsinghua)
Symmetrical disk prototypes		=	Machining		Improved performance (HIP)
Quadrant – double length prototype	=	=	Tendering		Machining
Halves – prototypes	=	=	Tendering		Machining/ Bonding test
TD18 quad with slots	11 GHz	=	Engineering design		

Accelerating structure		[#]	Status	Comments
AS for proto modules	12 GHz	14	Eng. design	
AS for CLIC	12 GHz	=	Eng. design	
AS PSI/Trieste	12 GHz	4	Machining	X-FEL
AS DDS UnM	12 GHz	1	Eng. design	



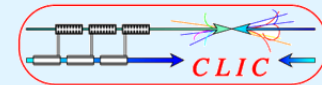
PETS		[#]	Status	Comments
PETS for SLAC	11 GHz	1	Final assembly	Damping mat.
PETS for test module	12 GHz	4	Eng. design	Collaboration with CIEMAT
PETS for stand-alone TS	12 GHz	2	Eng. design	
PETS for CLIC	12 GHz	=	Eng. design	
On-off mech. CLEX	12 GHz	2	Eng. design	
On-off mech. CLIC	12 GHz	=	Eng. design	





T18 (KS) N2

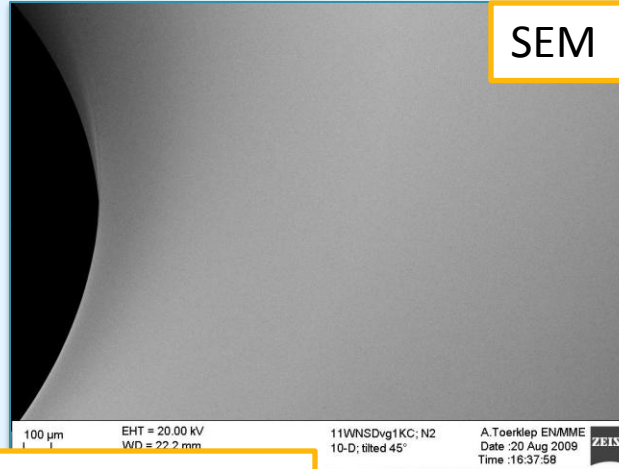
Under baking → shipping to SLAC
on 10.05.2010



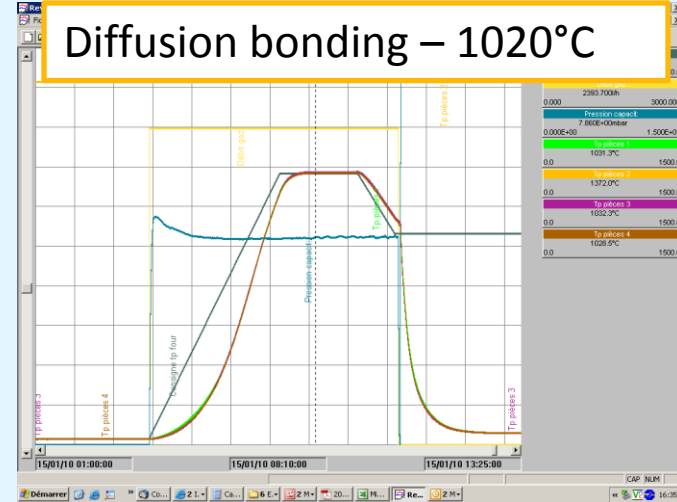
Inlet inspection



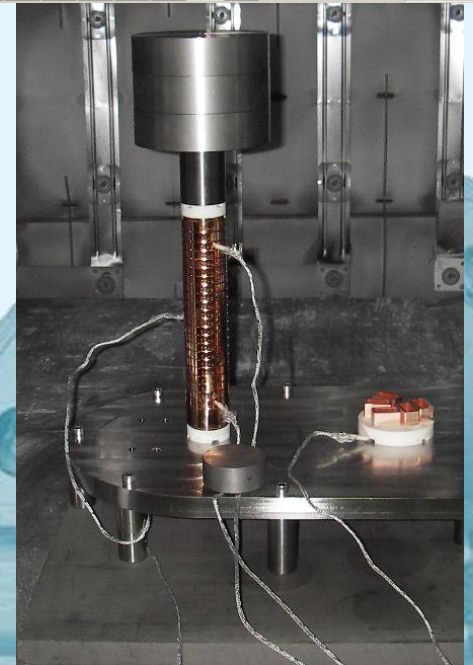
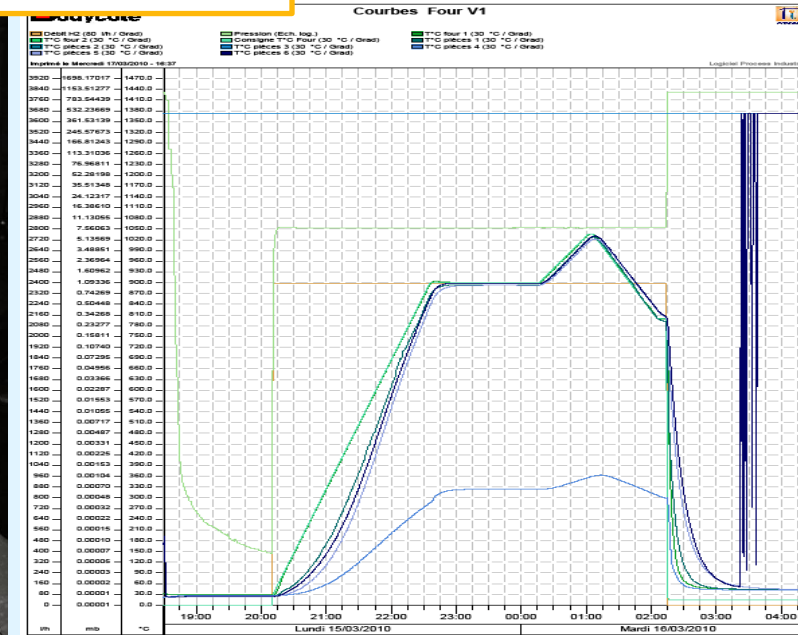
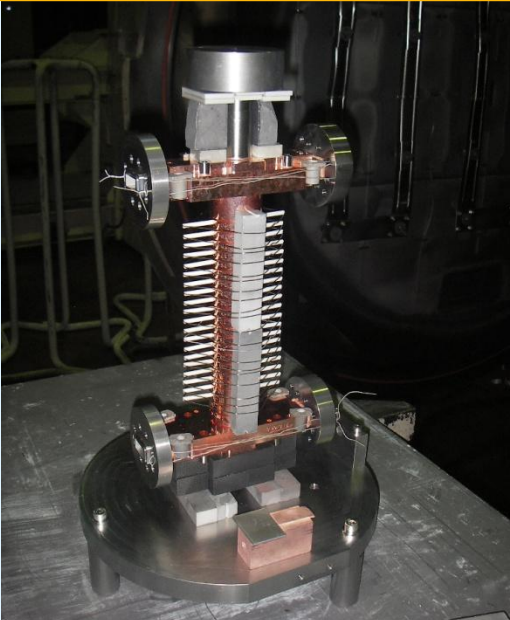
SEM



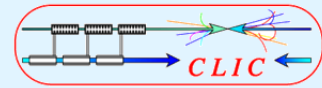
Diffusion bonding – 1020°C



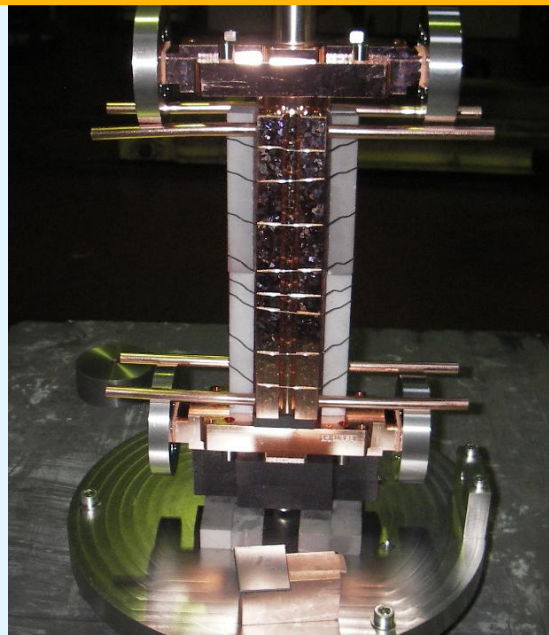
Brazing 35Au65Cu – 1021°C/1025°C



T18 (KS) N2



Preparation for final brazing



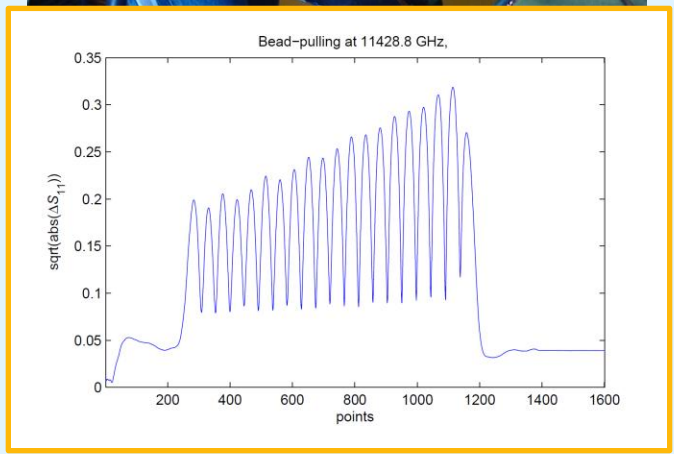
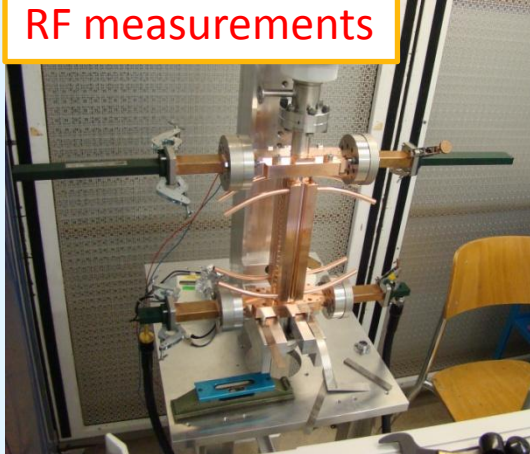
Flange welding under N2 injection



Preparation for baking



RF measurements



Machining at VDL

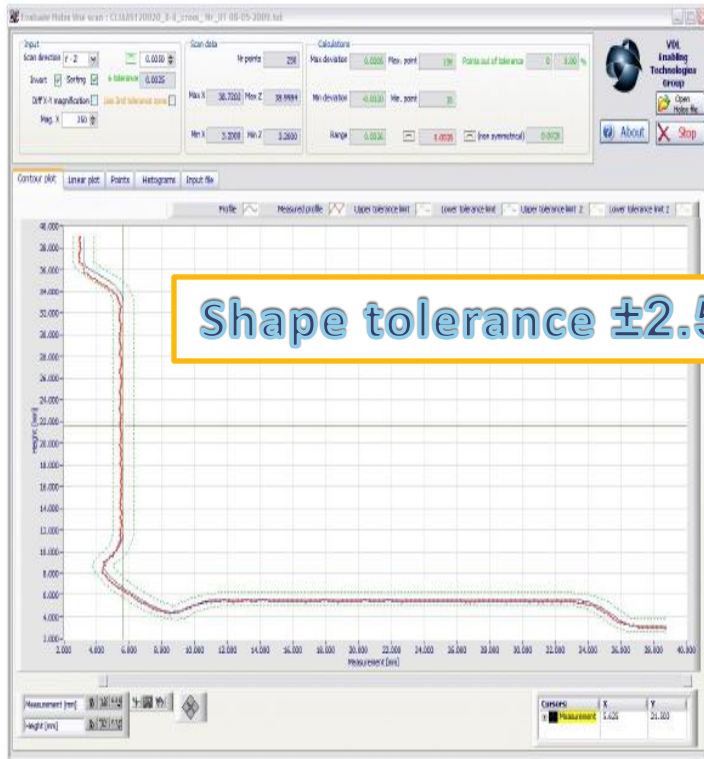
Inspection Report



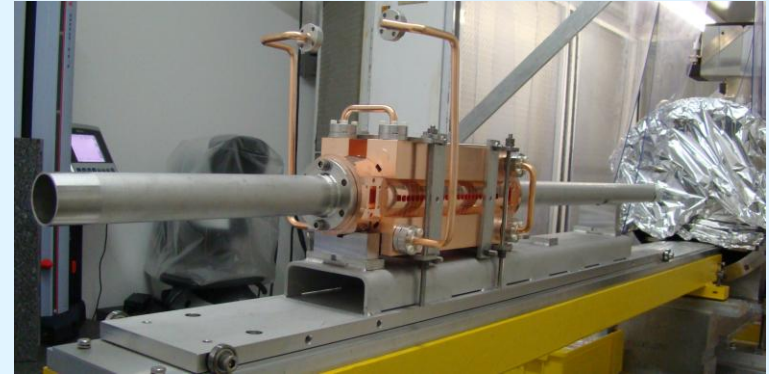
Drawing no.	CLIAAS120020	Prod. Nr.	1
Description	12WDSDBG1.8T disk 007		

Profile accuracy cross

0.005 A B



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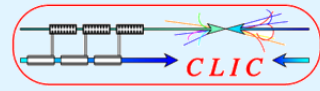


Disk 8.1

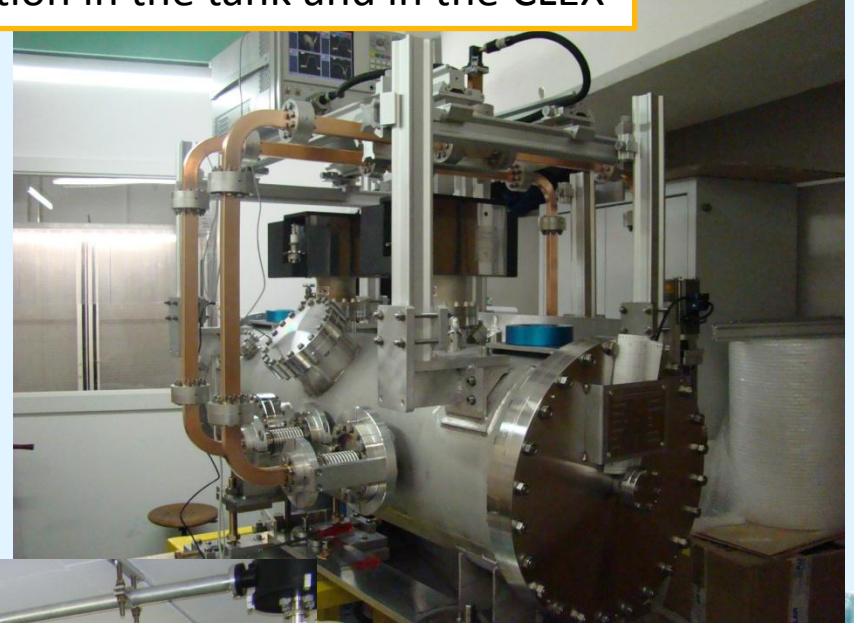
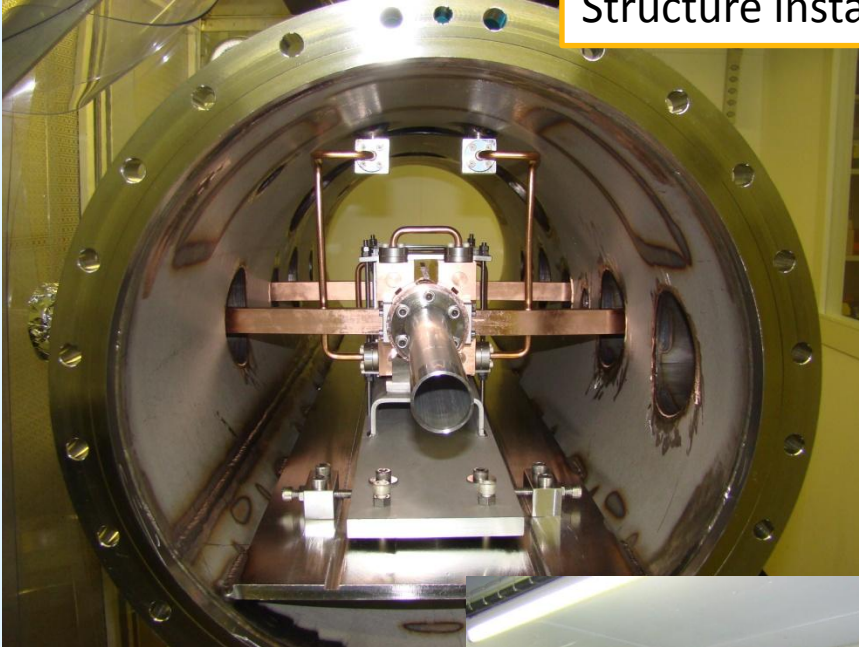


New CMM (Coordinate Measuring Machine) under procurement at CERN

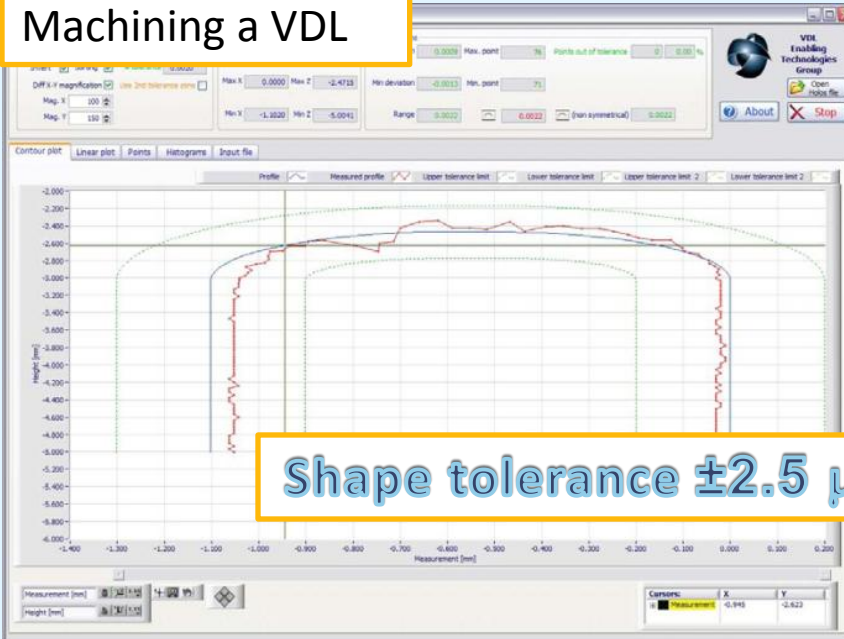
TD24 12 GHz (TBTS)



Structure installation in the tank and in the CLEX



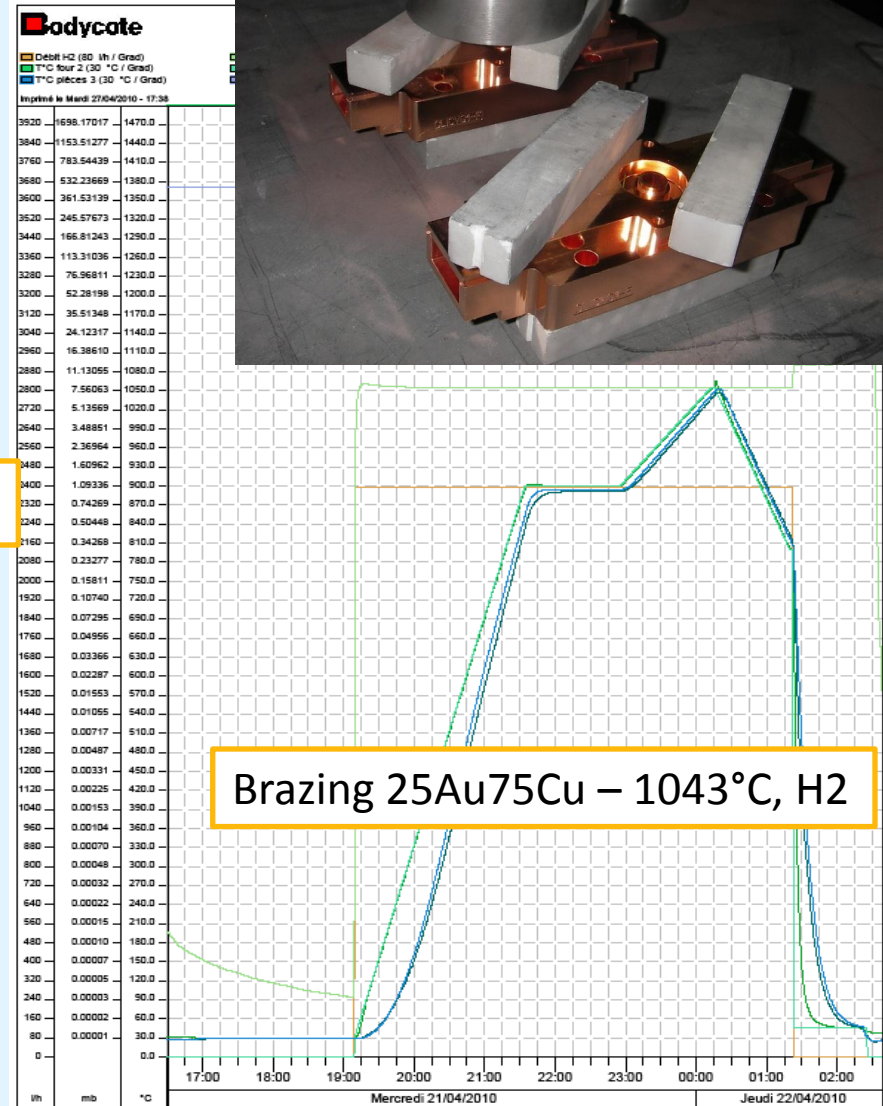
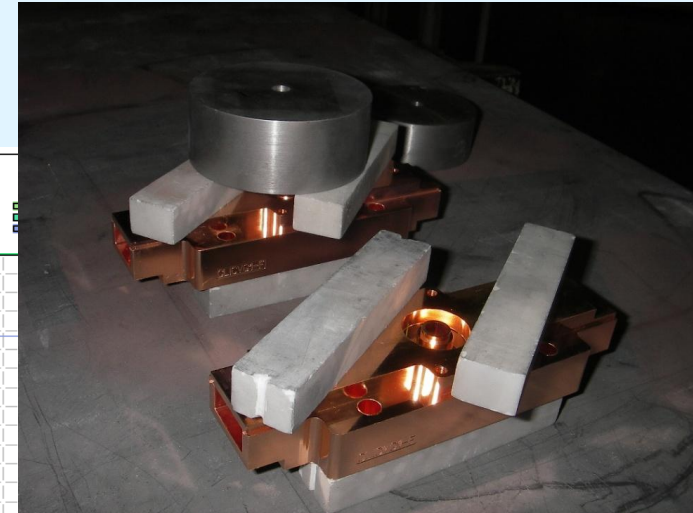
Machining a VDL



Shape tolerance $\pm 2.5 \mu\text{m}$

Status:

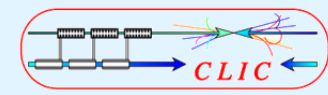
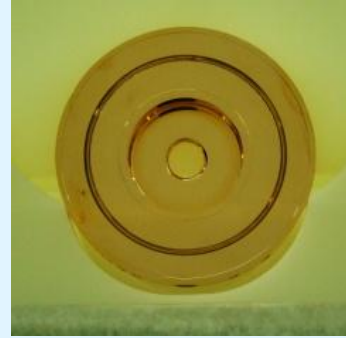
- machining of the couplers after brazing
- bonding of the disks on 04.05.2010



Brazing 25Au75Cu - 1043°C, H2

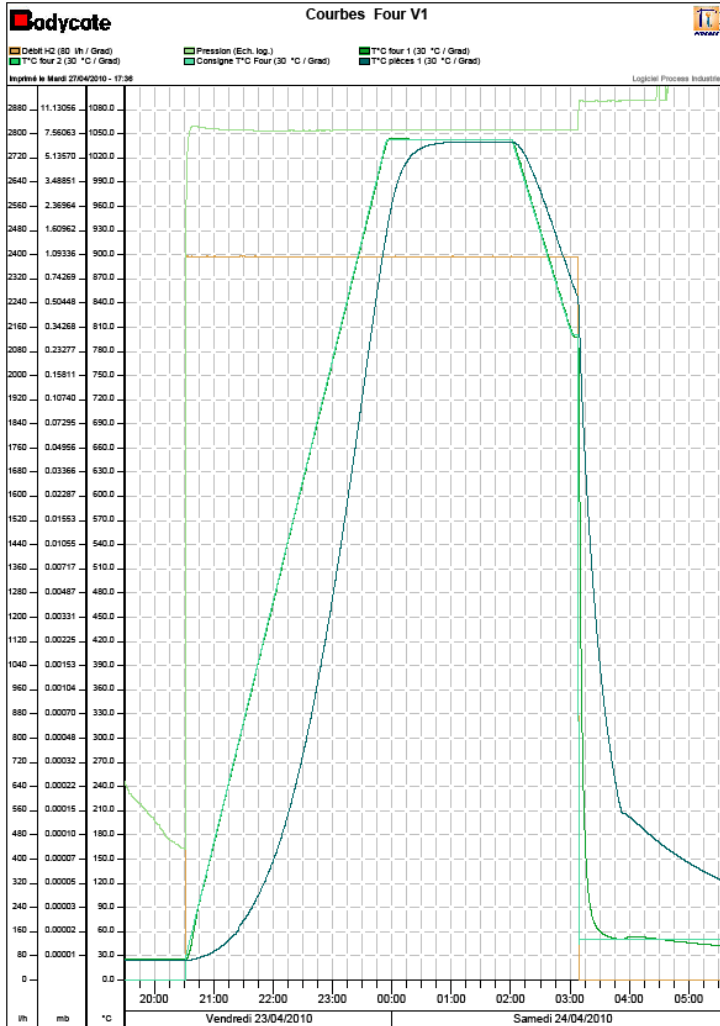
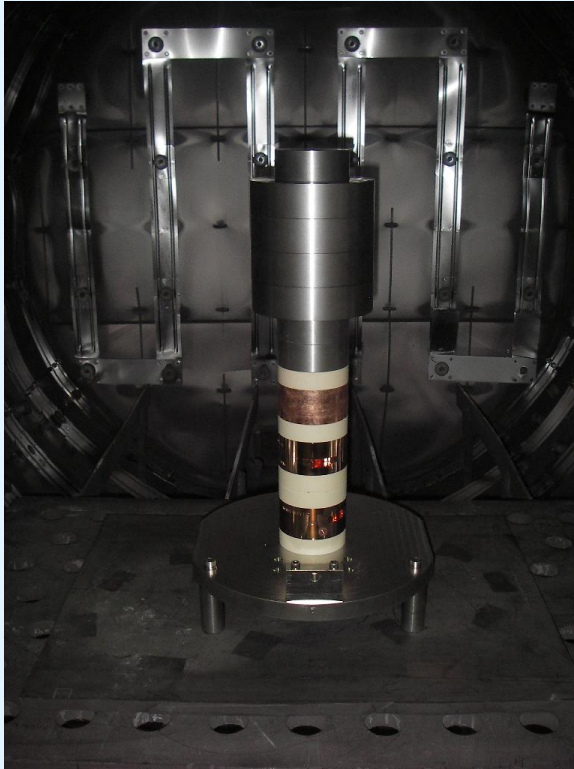


T24 C N1 – 12 GHz

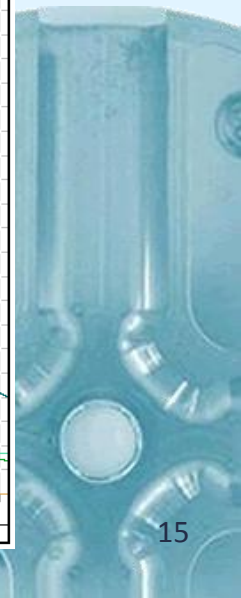


Status:

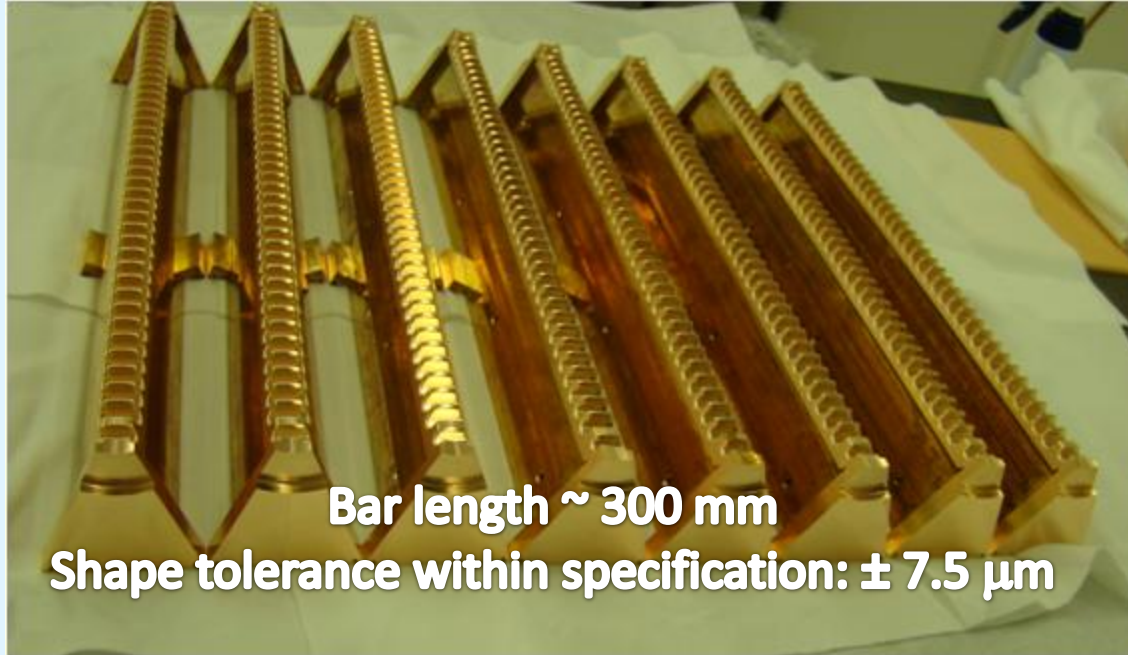
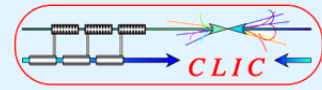
- machining of couplers under way
- bonding of the structure on 5.05.2010



Diffusion bonding of couplers:
1030-1040°C, H2

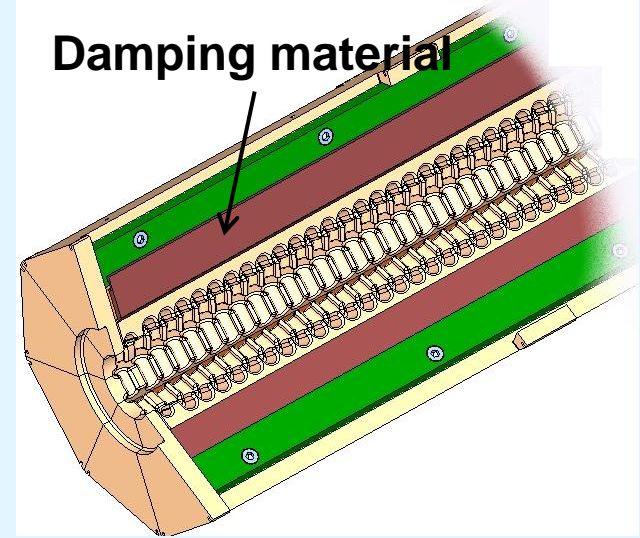


Fabrication of PETS at 11.4 GHz with damping material



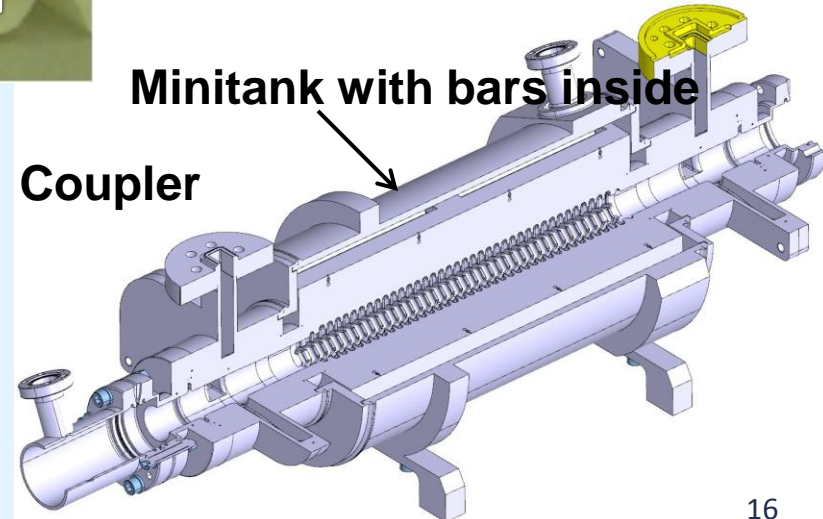
Bar length ~ 300 mm

Shape tolerance within specification: $\pm 7.5 \mu\text{m}$



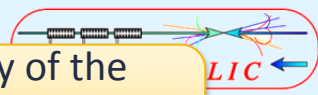
Status: assembly finished

Procedure as close as possible to the baseline,
but some difference due to design and
infrastructures

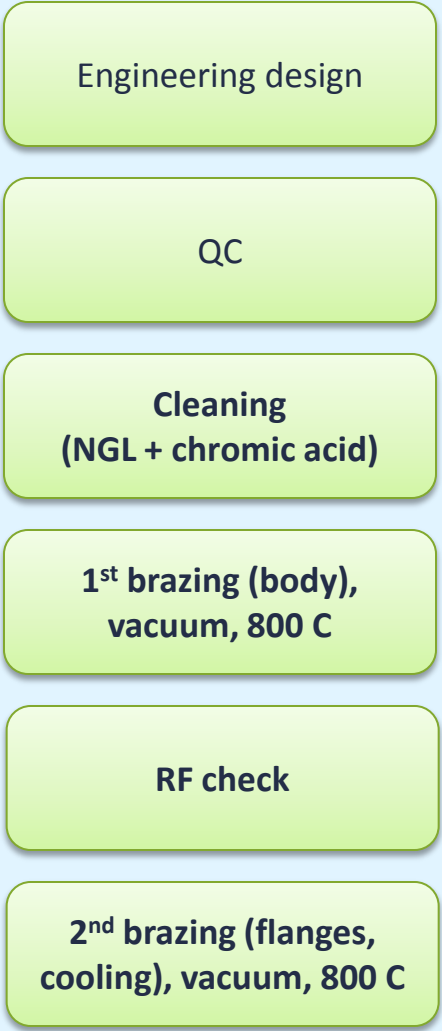




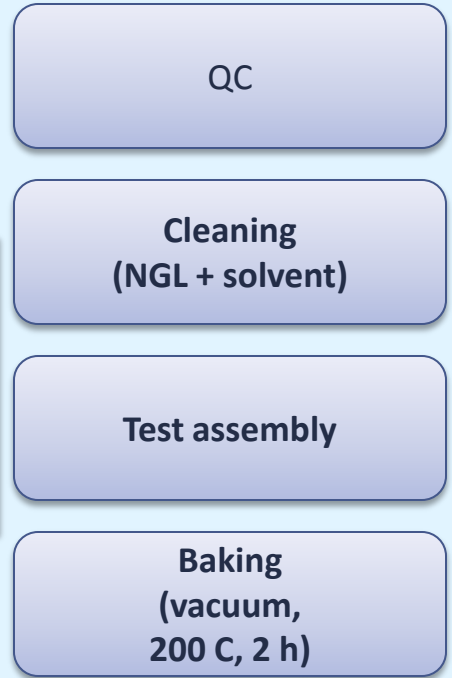
PETS: baseline manufacturing flow



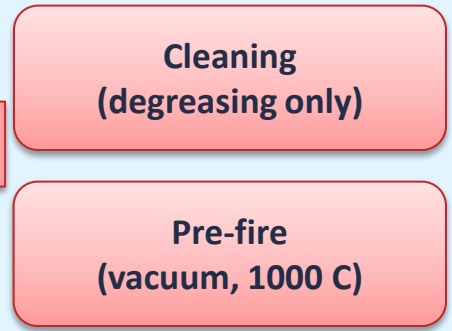
PETS couplers



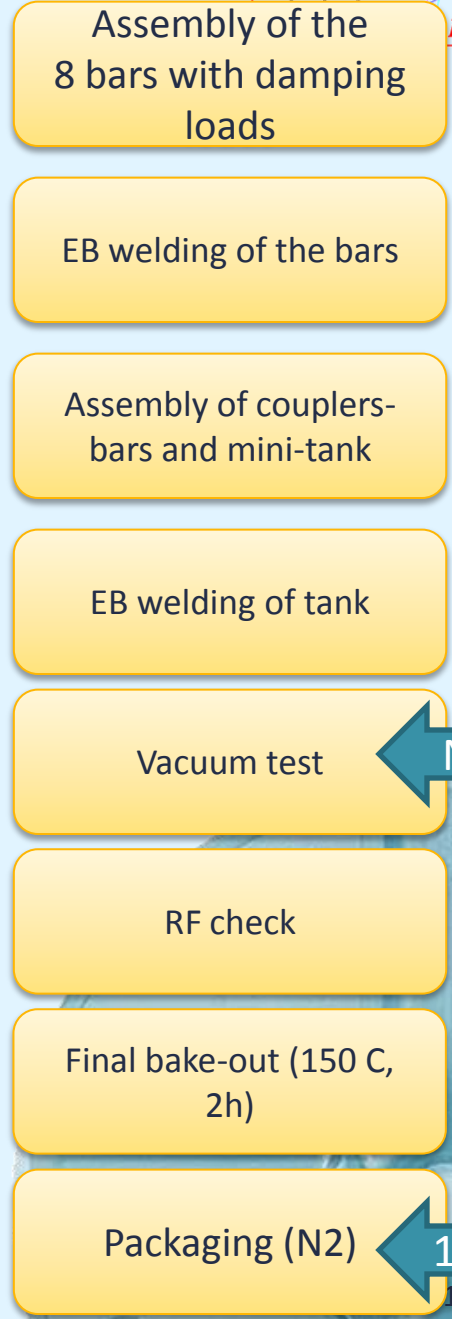
PETS bars



SiC



Assembly

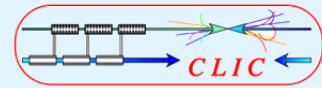


Now

12.05



PETS 11.4 GHz damping material



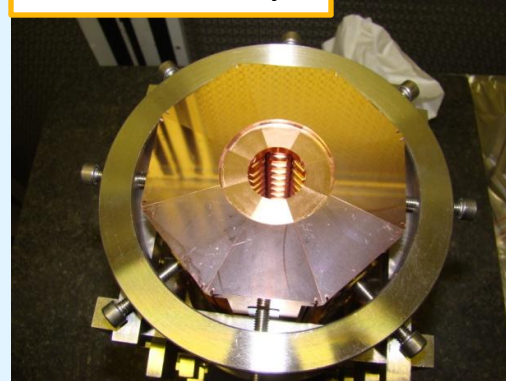
Cooling circuit brazing
Nickel base – 1030 °C



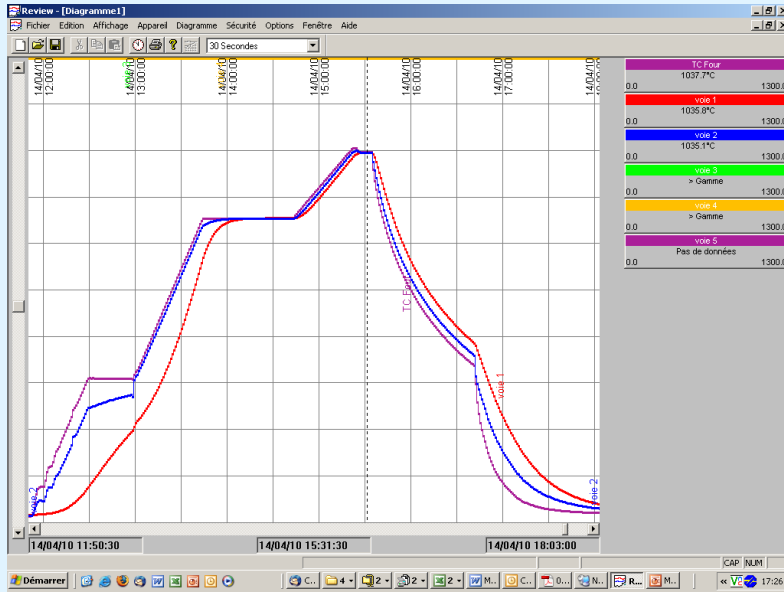
Bar with damping
material

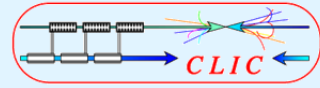


Bar assembly



Assembly in the tank





PRODUCTION CYCLE (ac. structures)				PRODUCTION CYCLE (PETS @ 11.4 GHz)			
Manufacturing	Assembly (bonding)	Tuning	Baking	Manufacturing	Assembly (EB welding)	RF meas.	Baking
10 wks	4 wks	2 wks	3 wks	10 wks	6 wks	1 wk	1 wk
Total: 19 wks (about 5 months)				Total: 18 wks (about 4.5 months)			

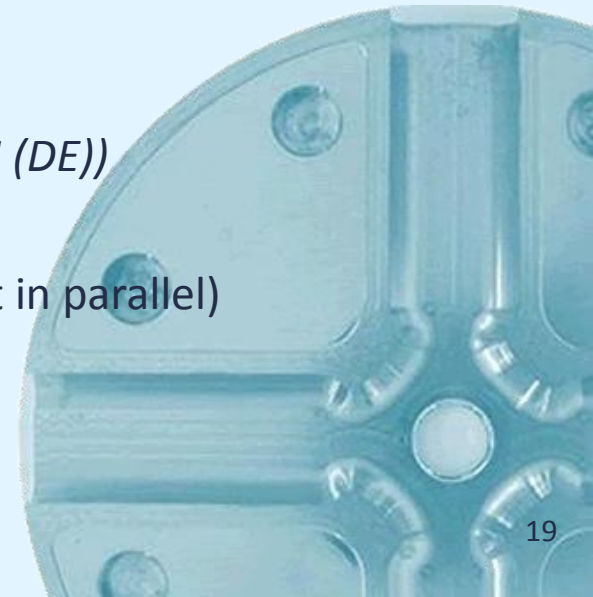
Firms qualified:

- Disks damped: VDL (NL), Mechacrome (FR), Savimex (FR)
- PETS: VDL (NL), Unitek (IT), KERN (DE), Comeb (IT)

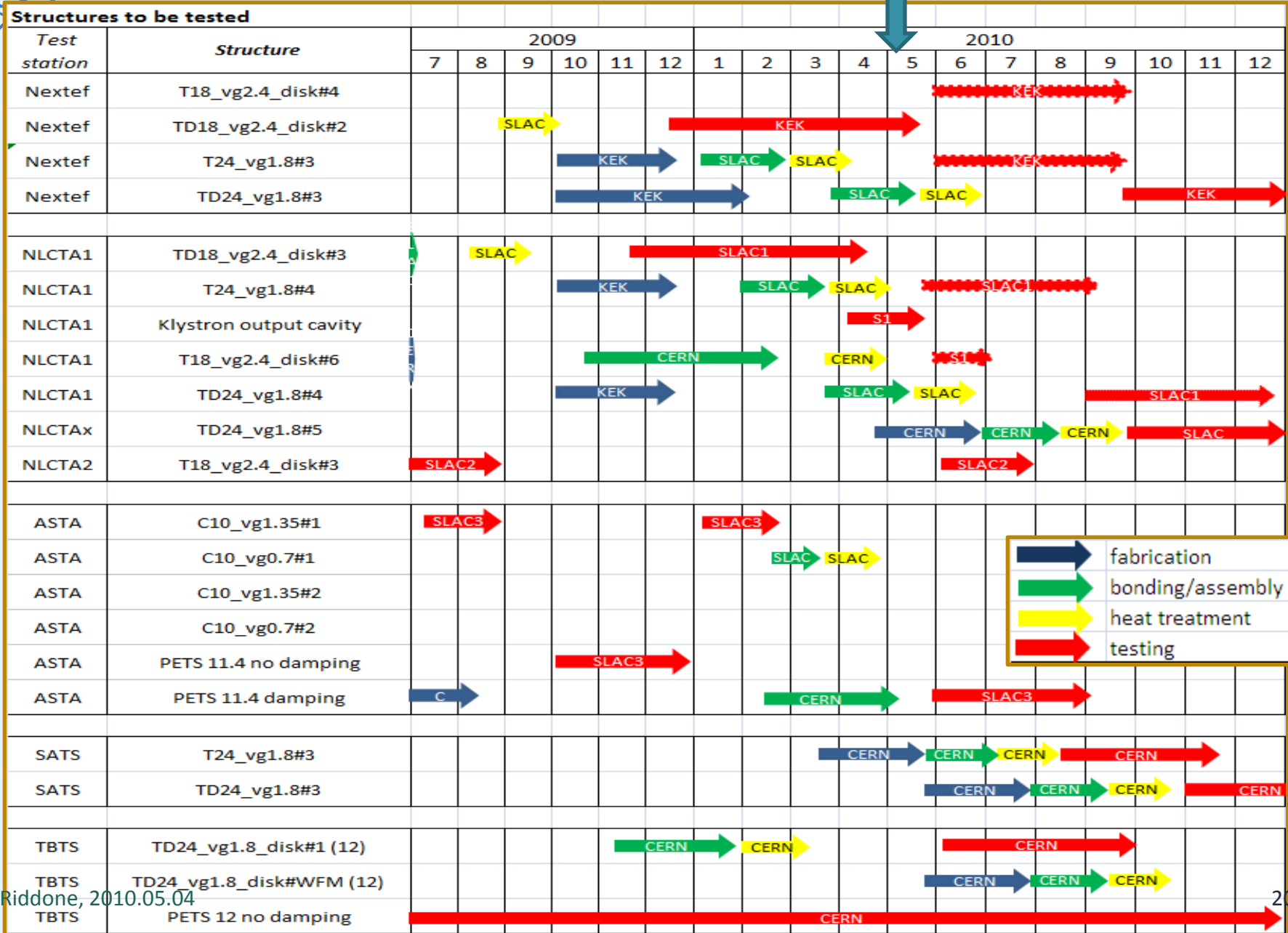
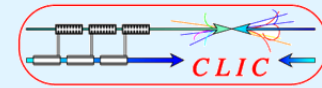
(effort continues to qualify new firms: DMP (SP), IPK (DE), KERN (DE))

For each structure, at least two units are manufactured (almost in parallel)

At present, potential capability up to 15 structures per year

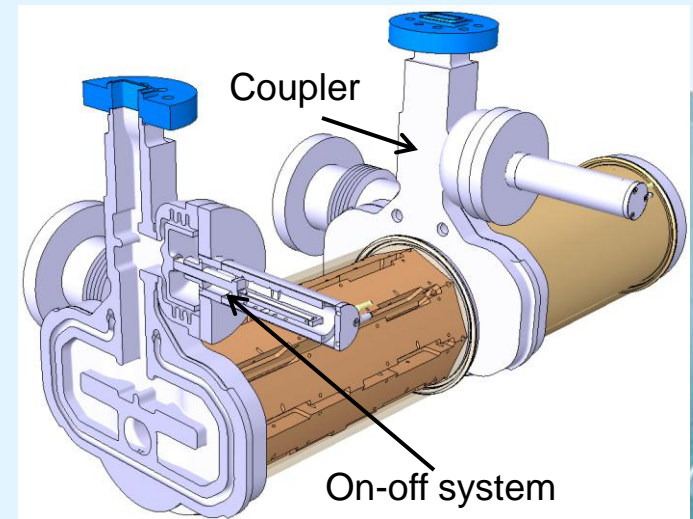
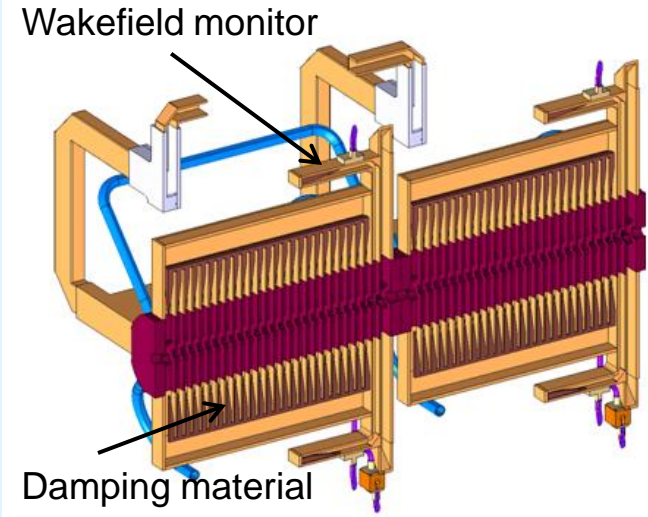


Master schedule



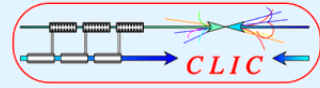
	fabrication
	bonding/assembly
	heat treatment
	testing

- **CDR – TD24 R05 SiC.KS**
 - Accelerating structure with all features: damping material, wakefield monitor and technical systems; under eng. design (**first structure at the end of 2010**). Assembly test with a prototype structure are scheduled in the coming weeks.
 - PETS with on-off system: under design. **On-off system to be tested in Q4, 2010**
Actuator prototype received on 3.5.2010
 - **Cost estimate** in needed by 2010: launched dedicated studies with three companies/institutes





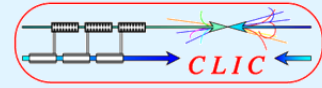
RF components



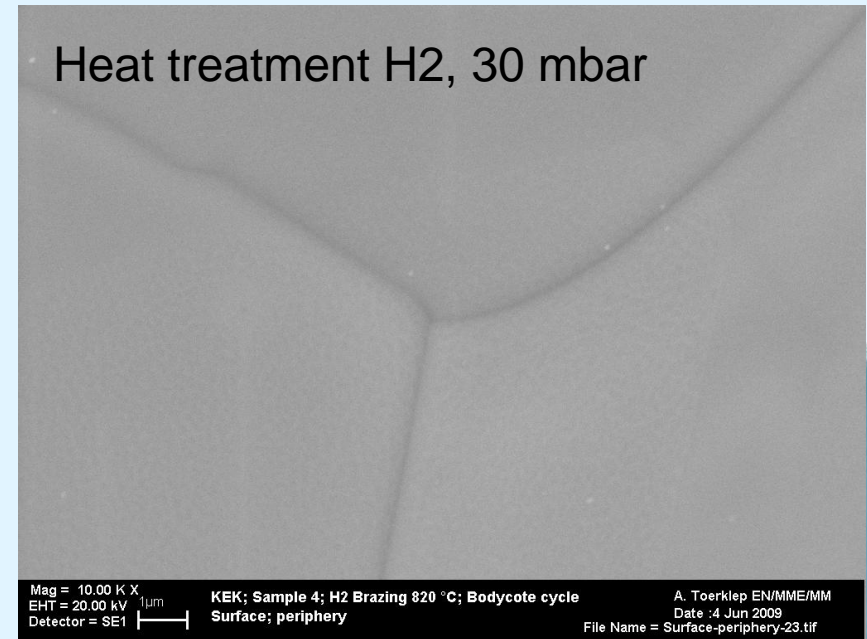
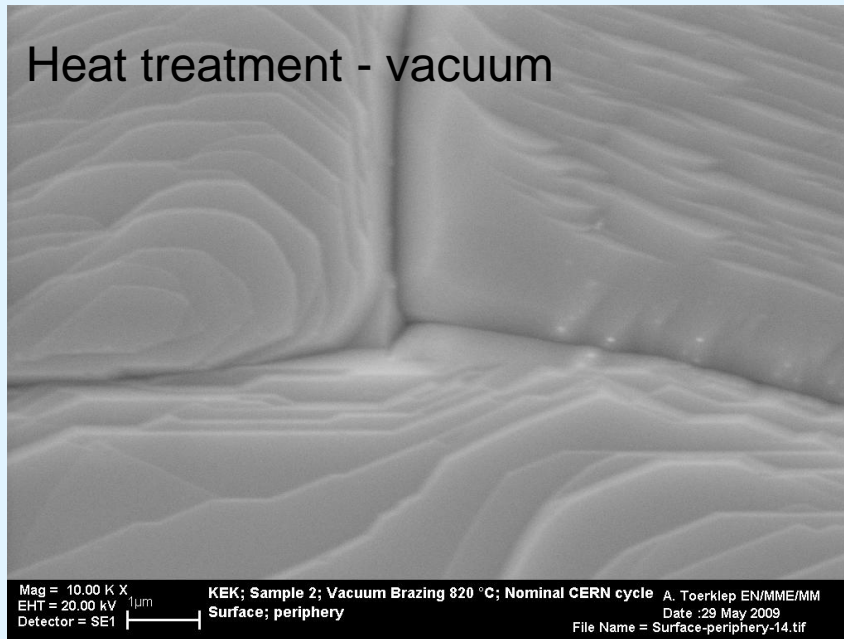
Component	Suppliers	TBTS	SATS	KEK	SLAC	TBL	PSI- XFEL	ST- XFEL
High-power loads [38]	CINEL (IT) Heeze (NL) VDL (NL) Cobham (UK)	7	3	2	2	18	3	3
Directional couplers [34]	Gycom (RU) Cobham (UK) Nikoha (JP) IHEP (CN)	5	6		1	14	5	3
Splitters [11]	VDL (NL)	4	2		1		2	2
Hybrids [4]	CINEL (IT) IHEP (CN)	2	2					
VPA [2]	Gycom (RU)	2						
Phase shifter [1]	Gycom (RU)	1						

Several RF components are needed for different test stands

Dedicated program: heat treatment comparison



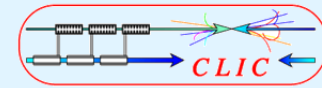
Motivation: understand why bonding under H₂ gives the best results (baseline)
Test with few samples conducted already in 2009 (before adopting baseline).
Some results are shown hereafter



Decision to pursue the investigation with several samples to increase statistics



Dedicated program: heat treatment comparison

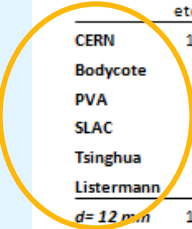


Samples under cleaning,
results expected by summer 2010

Production - surface after heat treatment
(faceting, bonding)

REFERENCE	820 C									1040 C																		
	Vacuum			Argon (mbar)			H2 (mbar)			H2 (1 bar)			Vacuum			Argon (mbar)				Hydrogen (mbar)			Hydrogen (1 bar)					
	w/o etch	Passiv ation	SLAC etch	w/o etch	Passiv ation	SLAC etch	w/o etch	Passiv ation	SLAC etch	w/o etch	Passiv ation	SLAC etch	w/o etch	Passiv ation	SLAC etch	w/o etch	Passiv ation	SLAC etch		w/o etch	Passiv ation	SLAC etch	w/o etch	Passiv ation	SLAC etch			
CERN	1	1	1	2	2	2							2	2	2	2	2	2										18
Bodycote				2	2	2	2	2	2				2	2	2	2	2	2	2	2	2							36
PVA							2	2	2										2	2	2							12
SLAC										2	2	2													2	2	2	12
Tsinghua										2	2	2													2	2	2	12
Listermann																									2	2	2	
d=85/80 mm	1	1	1	4	4	4	4	4	4	2	2	2	4	4	4	4	4	4	4	4	4	4	4	4	6	6	6	96

Different heat treatments/atmosphere
Different cleaning
Different places



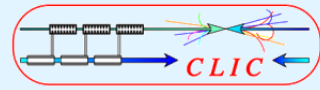
REFERENCE	820 C									1040 C																		
	Vacuum			Argon (mbar)			H2 (mbar)			H2 (1 bar)			Vacuum			Argon (mbar)				Hydrogen (mbar)			Hydrogen (1 bar)					
	w/o etch	Passiv ation	SLAC etch	w/o etch	Passiv ation	SLAC etch	w/o etch	Passiv ation	SLAC etch	w/o etch	Passiv ation	SLAC etch	w/o etch	Passiv ation	SLAC etch	w/o etch	Passiv ation	SLAC etch		w/o etch	Passiv ation	SLAC etch	w/o etch	Passiv ation	SLAC etch			
CERN	1	1	1	1	1	1				1	1	1													1	1	1	6
Bodycote				1	1	1	1	1	1	1	1	1													1	1	1	
PVA							1	1	1																			
SLAC																												
Tsinghua																												
Listermann																									1	1	1	
d=12 mm	1	1	1	2	2	2	2	2	2	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	48

DC sparks - XPS - H2 content

REFERENCE	820 C									1040 C																		
	Vacuum			Argon (mbar)			H2 (mbar)			H2 (1 bar)			Vacuum			Argon (mbar)				Hydrogen (mbar)			Hydrogen (1 bar)					
	w/o etch	Passiv ation	SLAC etch	w/o etch	Passiv ation	SLAC etch	w/o etch	Passiv ation	SLAC etch	w/o etch	Passiv ation	SLAC etch	w/o etch	Passiv ation	SLAC etch	w/o etch	Passiv ation	SLAC etch		w/o etch	Passiv ation	SLAC etch	w/o etch	Passiv ation	SLAC etch			
CERN	4	4	4	4	4	4	4	4	4				4	4	4	4	4	4	4	4	4	4	4	4				36
Bodycote				4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4							72
SLAC										4	4	4													4	4	4	24
	4	4	4	8	8	8	4	4	4	4	4	4	4	4	4	8	8	8	8	8	8	4	4	4	4	4	4	132

Ideas are
welcome!

Conclusions



- NLC/JLC fabrication technology validated for CLIC accelerating structures to 100 MV/m, adopted by CERN (since 09.2009)
 - First structure built by CERN T18 (high power tests are important): modifications implemented for 2nd structure after visit at SLAC
- Important milestone is the TD24 with SiC: first unit ready by end of this year
- Production of RF components is expanding
- Production capability up to 15 structures per year → higher than available testing slots
- A lot of work: involvement of other laboratories to exchange experience and expertise is essential
- Industrialization, mass production and cost study launched for few structure configurations